used also having a concentration between 0.0001% to 0.1%. For the KrF laser, an addition of xenon or argon may be used also having a concentration between 0.0001% to 0.1%. Gas replenishment actions are described below for gas mixture compositions of systems such as ArF, KrF, and XeCl excimer lasers and molecular fluorine lasers, wherein the ideas set forth herein may be advantageously incorporated into any of these systems, and other gas discharge laser systems.

GAS REPLENISHMENT

Halogen gas injections, including micro-halogen injections of, e.g., 1-3 milliliters of halogen gas, mixed with, e.g., 20-60 milliliters of buffer gas or a mixture of the halogen gas, the buffer gas and a active rare gas for rare gas-halide excimer lasers, per injection for a total gas volume in the laser tube 102 of, e.g., 100 liters, total pressure adjustments and gas replacement procedures may be performed using the gas handling module 106 preferably including a vacuum pump, a valve network and one or more gas compartments. The gas handling module 106 receives gas via gas lines connected to gas containers, tanks, canisters and/or bottles. Some preferred and alternative gas handling and/or replenishment procedures, other than as specifically described herein (see below), are described at U.S. patents no. 4,977,573, 6,212,214, 6,243,406 and 5,396,514 and U.S. patent applications no. 09/447,882, 09/734,459, 09/513,025 and 09/588,561, each of which is assigned to the same assignee as the present application, and U.S. patents no. 5,978,406, 6,014,398 and 6,028,880, all of which are hereby incorporated by reference. A xenon gas or other gas additive supply may be included either internal or external to the laser system according to the '025 application, mentioned above.

Total pressure adjustments in the form of releases of gases or reduction of the total pressure within the laser tube 102 may also be performed. Total pressure adjustments may be followed by gas composition adjustments if it is determined that, e.g., other than the desired partial

pressure of halogen gas is within the laser tube 102 after the total pressure adjustment. Total pressure adjustments may also be performed after gas replenishment actions, and may be performed in combination with smaller adjustments of the driving voltage to the discharge than would be made if no pressure adjustments were performed in combination.

Gas replacement procedures may be performed and may be referred to as partial, mini- or macro-gas replacement operations, or partial new fill operations, depending on the amount of gas replaced, e.g., anywhere from a few milliliters up to 50 liters or more, but less than a new fill, such as are set forth in the 09/734,459 application, incorporated by reference above. As an example, the gas handling unit 106 connected to the laser tube 102 either directly or through an additional valve assembly, such as may include a small compartment for regulating the amount of gas injected (see the '459 application), may include a gas line for injecting a premix A including 1%F_2:99%Ne or other buffer gas such as He, and another gas line for injecting a premix B including 1% rare gas:99% buffer gas, for a rare gas-halide excimer laser, wherein for a F_2 laser premix B is not used. Another line may be used for injecting a gas additive or gas additive premix, or a gas additive may be added to premix A, premix B or a buffer gas. Another line may be used for total pressure additions or reductions, i.e., for flowing buffer gas into the laser tube or allowing some of the gas mixture in the tube to be released, possibly accompanying halogen injections for maintaining the halogen concentration. Thus, by injecting premix A (and premix B for rare gas-halide excimer lasers) into the tube 102 via the valve assembly, the fluorine concentration in the laser tube 102 may be replenished. Then, a certain amount of gas may be released corresponding to the amount that was injected to maintain the total pressure at a selected level. Additional gas lines and/or valves may be used for injecting additional gas mixtures. New fills, partial and mini gas replacements and gas injection procedures, e.g., enhanced and ordinary micro-halogen injections, such as between 1 milliliter or less and 3-10 milliliters, or more depending on the degree of stability desired, and any and all other gas replenishment actions are initiated and

controlled by the processor 116 which controls valve assemblies of the gas handling unit 106 and the laser tube 102 based on various input information in a feedback loop. These gas replenishment procedures may be used in combination with gas circulation loops and/or window replacement procedures to achieve a laser system having an increased servicing interval for both the gas mixture and the laser tube windows.

LINE NARROWING

A general description of the line-narrowing features of embodiments of the laser system particularly for use with photolithographic applications is provided here, followed by a listing of patent and patent applications being incorporated by reference as describing variations and features that may be used within the scope of the preferred embodiments herein for providing an output beam with a high spectral purity or bandwidth (e.g., below 1 pm and preferably 0.6 pm or less). These exemplary embodiments may be used along with the wavefront compensating optic 3, 13, 13 described above. For the F_2 laser, the optics may be used for selecting the primary line λ_1 only of multiple lines around 157 nm, or may be used to provide additional line narrowing as well as performing line-selection, or the resonator may include optics for line-selection and additional optics for line-narrowing of the selected line, and line-narrowing may be provided by controlling (i.e., reducing) the total pressure (see U.S. patent application no. 60/212,301, which is assigned to the same assignee and is hereby incorporated by reference). Line-narrowing of the broadband emission of the ArF and/or KrF lasers may be as set forth below.

Exemplary line-narrowing optics contained in the optics module 110 include a beam expander, an optional interferometric device such as an etalon or a device having a pair of opposed non-planar reflection plates such as may be described in the 09/715,803 or 60/280,398 applications, which are assigned to the same assignee as the present application and are hereby incorporated by reference, and a diffraction grating, and alternatively one or